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Energy and protein contents in pastures at different times of the year and feeding to meet animal nutrient requirements

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Introduction

Pasture is an integral part of ruminant animal production. In Southern Australia where rainfall is relatively high, animal production systems rely heavily on pastures to produce milk, wool and meat because it is by far, cheaper than grain-feeding. However, the profitability of a pasture-based enterprise like any other livestock venture, depends on the efficiency with which the animals utilise the nutrients from pastures to meet their requirements for maintenance and production. One of the key decisions in a grazing enterprise is how to manage the feed available in order to minimise costs and maximise output of animal products. Setting stocking rate to annual pasture production and matching feed available to animal requirements are the key elements to ensure that this is achieved. However, as the season changes, so does the nutrient composition of pastures. Furthermore, nutrient requirements vary depending on the age and physiological state of the animal. Schut *et al.* (2006) reported that the nutritional value of pastures declines by 0.03 and 0.06 MJ ME/kg DM/day for leaves and stems respectively at 18°C, but this decline is negligible at 12°C.Therefore, livestock farmers require detailed information about the feedstuffs of their herds in order to best achieve production goals, whether they are concerned with economic efficiency, nutrient efficiency or maximum yields.

From an animal nutrition perspective, the most important components of pasture quality are energy, dry-matter digestibility and crude protein contents. Among the chemical components of forage dry matter, carbohydrates account for the single largest proportion at around 70–80% (Abe, 2007). These carbohydrates are a major source of energy and are generally classified into structural and non-structural carbohydrates. Neutral Detergent Fibre (NDF) is a measure of the amount of structural carbohydrate in the plant and includes both digestible (hemicellulose), less digestible (cellulose) and indigestible (lignin) components. ADF – Acid Detergent Fibre is the amount of indigestible carbohydrate. Voluntary dry matter intake is critical to animal performance because cell-wall concentration of forages is negatively associated with intake of forage diets due to ruminal fill. Beck et al. (2007) reported that when in situ or in vitro NDF digestibility increased by 1% in corn silage diets, dry matter intake increased by 0.17 kg and milk yield increased by 0.25 kg. For the purpose of this paper, the focus is on the following three main attributes; Metabolisable Energy (MJ/Kg), Protein (%) and Fibre (%) contents of pastures in relation to animal requirements in different physiological states.

The aims and objectives of this paper include:

1. To highlight the nutrient composition of common pasture species with emphasis on crude protein, metabolisable energy, acid detergent fibre and dry matter digestibility.

2. To discuss the variations in protein, energy and digestibility of pasture at different times of the year.

3. To discuss the seasonal and breed variations in body condition scores, liveweight and daily gains in beef heifers grazing native pastures in Tasmania.

4. To discuss the energy and protein requirements of dairy cattle at different physiological states and ages.

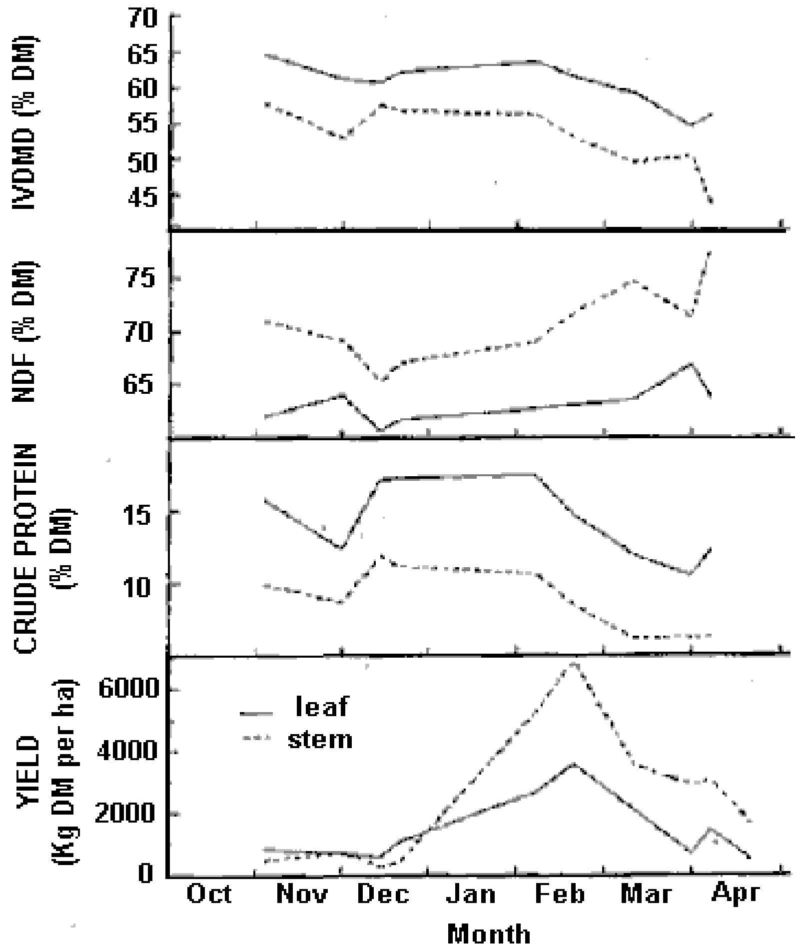
Energy and protein contents of pastures

The feeding value of pastures is determined mainly by its metabolisable energy, crude protein and dry matter digestibility. Michell (1973) published the digestibility and voluntary intake measurements on regrowths of six Tasmanian pasture species. The gross energy levels and relationship with digestibility and chemical composition were published the following year (Michell, 1974), while Walsh and Birrell (1987) published the chemical composition and nutritive value of five pasture species in South-Western Victoria. Ru and Fortune (2000) reported the nutritive values for South Australian subterranean clover. A more recent summary of average nutrient composition of common forage crop/pasture species extracted from a large database maintained by the NSW DPI is depicted in Table 1 below.

Pasture	CP (%)	ME (MJ/kg DM)	ADF (%)	DMD (%)
Ryegrass	16	9.8	30.5	65
Lucerne	18	9.2	36.1	62
Barley	13	11.3	16.3	75
Wheat	14	11.4	16.5	76
Clover	15	9.9	28.9	66
Cocksfoot	12	8.8	36.4	59
Canola	19	10.3	28.1	68
Chicory	18	9.8	31.9	65
Lupins	30	11.1	27.2	74
Linseed	32	11.5	24.9	77
Oats	11	10.4	23.3	69
Triticale	12	12.4	7.2	83

It is evident from Table 1 that the CP content ranges from 11% in oats to 30% in lupins and linseed, while metabolisable energy ranges between 8.8 and 12.4MJ/kg DM. Triticale has the best digestibility (83%) and the lowest acid detergent fibre at 7.2% clearly portraying the inverse relationship between the two indices of pasture quality. Generally, it is recommended that ME values for dry stock should not be less than 7 MJ/kg DM and CP not less than 10%, but the requirements are much higher for production purposes.

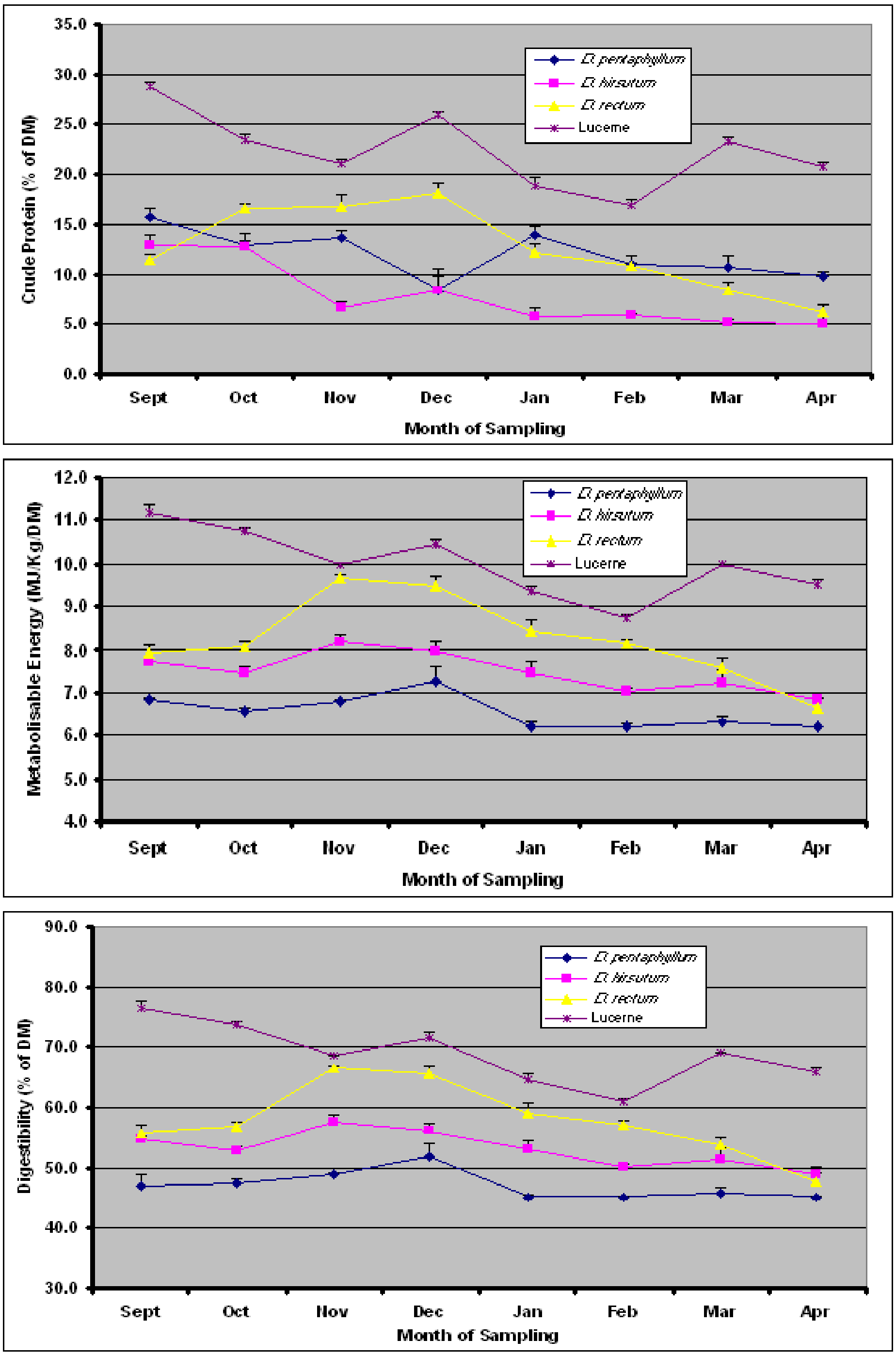
Variations in protein, energy and digestibility of pasture at different times of the year
With the decline in pasture quality in Southern Australia, the development of management strategies to improve nutrient supply for grazing animals is essential and requires a clear understanding of the interaction between plants and animal requirements (Ru and Fortune 2000). Figure 1 below depicts the changes in green dry matter (DM) yield, crude protein (CP%), fibre (NDF) and digestibility (IVDMD) content of green dry matter for a fertilised, rain-grown, Rhodes grass pasture during spring, summer and autumn.



(Figure 1 Source: Moss 2001)

All measures of pasture quality were much higher for leaf than stem and quality of pastures declined with advancing maturity and senescence. Changes in digestibility were associated with increasing NDF (fibre) content of the pasture. Yields increased rapidly from October to January, but with a reduction in leaf percentage as the season progressed and the grass matured. High yields of stem were maintained into autumn but the green leaf began to decline from March (Figure 1).

In Tasmania, Davies and Lane (2003) investigated and compared the seasonal changes in the nutritive values of Lucerne and 3 species of *Dorycnium* spp with regard to crude protein, metabolisable energy and dry matter digestibility. Their results are depicted in Figure 2 below.

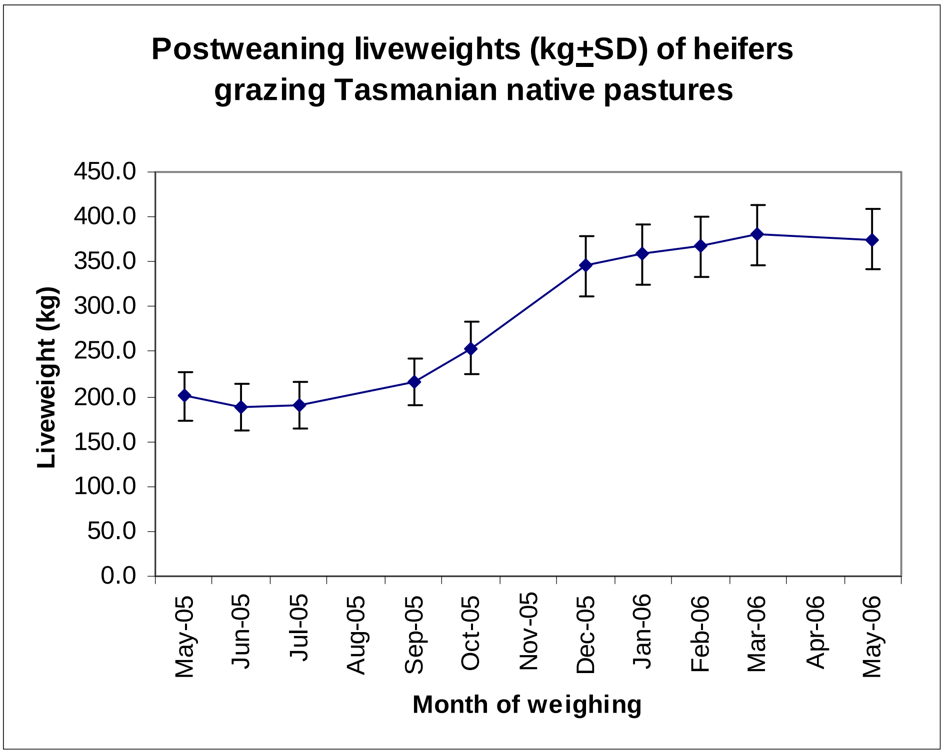


(Figure 2 Source: Davies and Lane, 2003)

The data clearly indicated that there was an overall decrease in crude protein content, ME and digestibility for all species from the start of the growing season to the end and at all sampling times, lucerne had the highest CP (18-30%), ME (9-11 MJ/kg DM) and DMD (60-77%). It was inferred that although the quality of feed produced was lower than other forage crops, the inherent characteristics of *Dorycnium* spp. meant that its production could occur under adverse conditions of low rainfall periods. This is where *Dorycnium spp*. has the potential to be included in grazing systems as a late season or reserve of forage when feed gaps occur and help maintain stock condition and/ or reduce losses in animal production (Davies and Lane 2003).

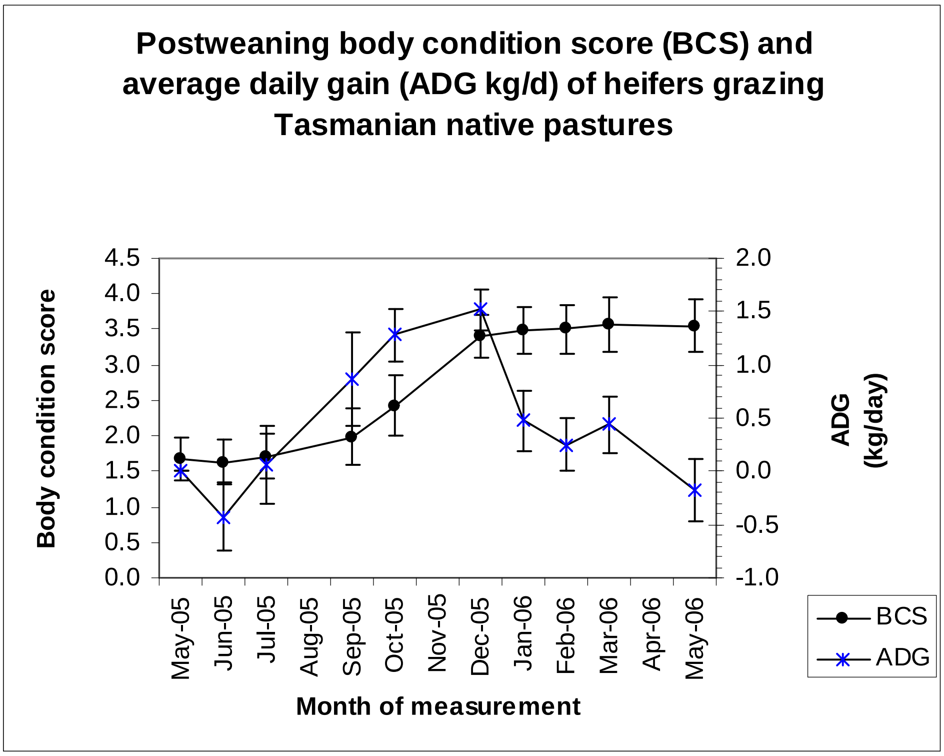
Seasonal and breed variations in liveweight, body condition scores and daily gains in pasture-fed cattle

Investigations into seasonal variations in post-weaning growth performance of Hereford, Angus, Hereford x Angus and Hereford x Saler heifers within the same herd grazing native pastures in Tasmania (Malau-Aduli and Dunbabin 2007) revealed that regardless of breed, liveweight, body condition scores and average daily gains followed a typical sigmoid curve pattern (Figure 3) in sharp contrast to the observed linear increase in liveweight as age increased in lot-fed cattle (Malau-Aduli *et al* 2007).



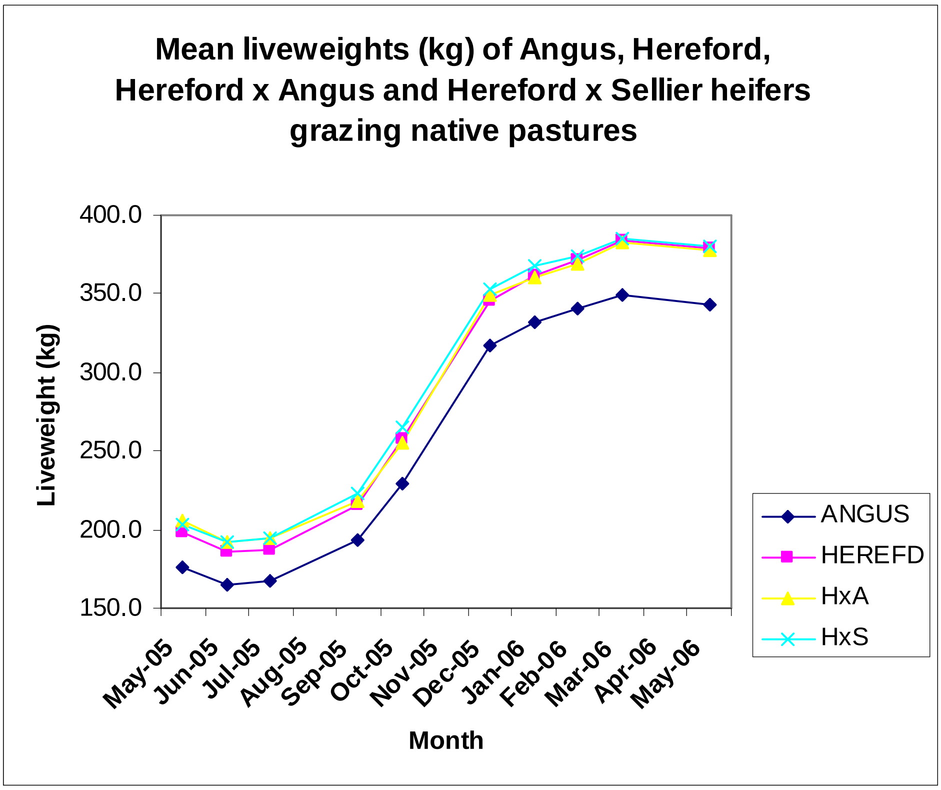
(Figure 3 Source: Malau-Aduli and Dunbabin 2007)

As depicted in Figure 3, there was a decline in average liveweight from 200 kg in May to 188 kg in June, a continuous monthly increase through to March 2006 when it reached a peak (380 kg) before a final decline to 375 kg in May. Body condition score ranged from 1.6 to 3.6 while average daily gains ranged from -0.4 to 1.5 kg/d (Figure 4).

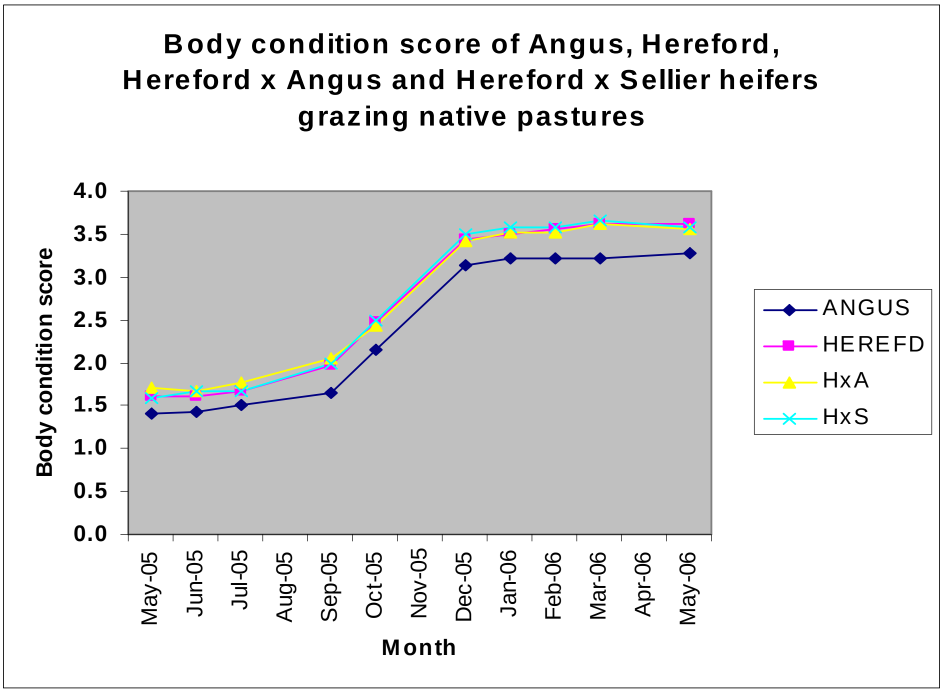


(Figure 4 Source: Malau-Aduli and Dunbabin 2007)

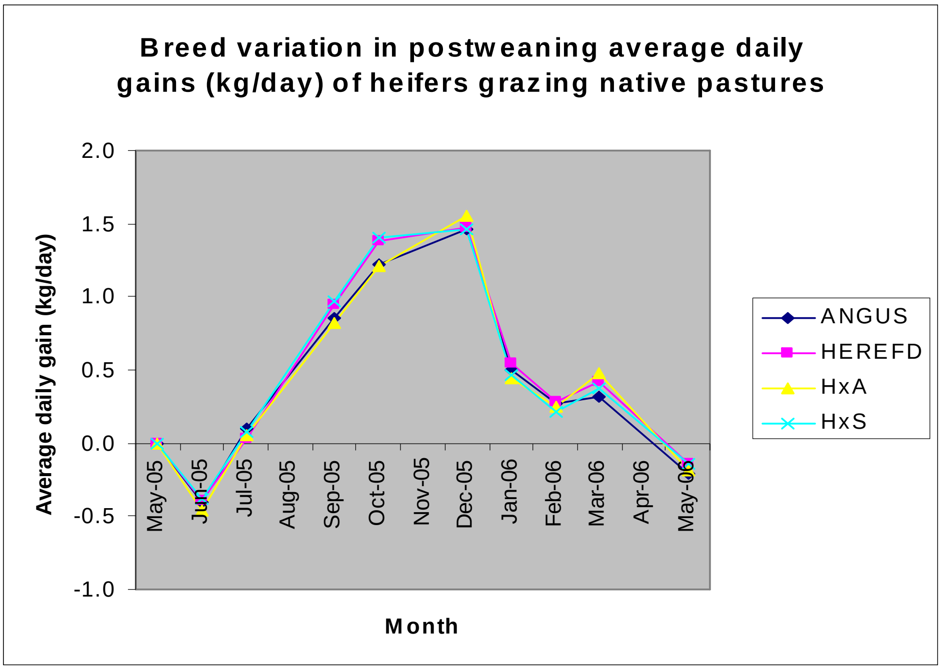
Significant genetic variation was observed between the different cattle breeds in that body condition score and liveweight of purebred Angus heifers were lower than those of purebred Hereford and their crosses with Angus and Saler (Figures 5-7). Average liveweight of the Angus breed ranged from 164-349 kg (Figure 5), with body condition score ranging from 1.4 to 3.3 (Figure 6) compared to the Hereford (186-383 kg, 1.6-3.6), Hereford × Angus (192-383 kg, 1.7-3.6) and Hereford × Saler (192-385 kg, 1.6-3.7), respectively (Figure 5). The average daily gain of Angus heifers was not different from those of Hereford and their crosses (Figure 7) indicating that the Angus was perhaps better in terms of feed efficiency since they probably ate less and gained the same weight as the heavier breeds that must have eaten more commensurate with their maintenance requirements.



(Figure 5 Source: Malau-Aduli and Dunbabin 2007)



(Figure 6 Source: Malau-Aduli and Dunbabin 2007)



(Figure 7 Source: Malau-Aduli and Dunbabin 2007)

It is therefore obvious that the decline in pasture quality as the season progresses is equally reflected in the liveweights, body condition scores and average daily gains of grazing livestock. An understanding of animal nutrient requirements in different physiological conditions is paramount to mapping out strategies of how best to manage our feed resources in order to ensure that the animals are meeting these requirements during the year.

Animal Nutrient Requirements

Fertilised grass supplies only 8-9 MJ ME/kg DM and will only support gains up to 0.25 kg/day by weaners (Moss and Murray 1992). The weaned calf is able to consume leafy pasture at about 2.5% of her live weight, or pasture plus concentrate to about 2.8% of live weight per day (Moss and Goodchild 1992). This implies energy is the most limiting nutrient in pasture-fed animals. Therefore, as depicted in Table 1, to maintain an average daily gain of 0.7 kg/day, the weaned calf needs a diet supplying 16% crude protein and 11 MJ ME/kg dry matter (Moss 2003). Declining quality of mature pastures in autumn may necessitate additional concentrate, an increase in the protein content of the concentrate, or the feeding of alternate higher quality forages or hay. In spring and summer, a concentrate of grain plus a protein meal (e.g. cottonseed meal, canola, sunflower, soybean meal) containing 16-18% CP is required, fed at 1.5 to 2 kg per heifer per day.

Table 1: Energy and protein requirements of dairy cattle at different ages, liveweights and physiological states (Sources: DeLaval 2007; Moss and Murray 1992; Moss 2003)

Age (months)	Liveweight (kg)	Physiological State	CP (%)	ME (MJ/kg/DM)
3-8	60-200	Post-weaning	16	11
12-15	300-350	Breedable Yearling	14	10
15-24	350-550$^+$	Pregnant	12	9
24$^+$	600-700$^+$	Lactation	12-19	9.8-12.1

When the Holstein-Friesian heifer reaches about 200 kg live weight (8-9 months) she requires a dietary energy density around 10 MJ ME/kg DM, with protein content of 14 % CP (Table 1). Leafy green fertilised pasture can satisfy her protein needs, but energy levels in grass pasture (8.5 to 9 MJ ME/kg) will only support liveweight gains of 0.4-0.5 kg/day. She still requires additional digestible energy supplementation to maintain growth rates of 0.7 kg/day. This can be achieved with cereal grain fed at 1.5 to 2.0 kg/day.

Above about 300 kg live weight (12 months of age), the heifer can achieve live weight gains up to 0.7 kg/day on good quality grass pasture supplying 9 MJ ME/kg DM plus 12 % protein. However, as such pasture is usually only available during the wet season or with irrigation, it may be limited for replacement heifers, except possibly in high rainfall areas - and concentrate supplementation should be considered. The mated heifer (>350 kg) is now building up her body condition in readiness for her subsequent lactation, so her requirement for protein to energy in her diet is lower. She still needs more protein and energy than the adult dry cow as she is continuing to grow muscle tissue plus provide the nutrients for her developing foetus. A dietary intake of 12% CP will meet her requirements and those of her calf. She needs a dietary energy concentration of about 9 MJ ME/kg DM. These requirements can be met by fertilised, green pasture, or with grain supplements fed at 0.5 to 1.5 kg/day, if pasture quality and quantity are not adequate.

Table 2. Feed intake and metabolisable energy (MJ ME/day) required to maintain liveweight gains of 0.6 to 0.7 kg/day in cattle (Source: Moss, 2003).

Liveweight	DM Intake	Required Metabolisable Energy Intake (MJ ME/day)	
(kg)	(kg/day)	Gain = 0.6 kg/day	Gain = 0.7 kg/day
100	2.8	29	32
200	5.0	47	50
300	7.0-7.5	65	70
400	9.0-10.0	80	85
500	11.0-12.0	98	105
550	13.0	108	115
600	15.0	118	126

Maintenance:

Fernandes *et al.* (2007) defined the energy required for maintenance (NEm) as the amount of energy used in basal metabolism and lost as heat when an animal is fasting (also known as fasting HP) plus the heat of activity and the additional energy lost when an animal consumes enough feed to maintain a static body energy content (heat increment at zero energy balance). Tedeschi *et al.* (2002) found that in beef cattle, the NEm averaged 77.2 kcal/kg$^{0.75}$EBW and was similar for bulls and steers. However, the efficiency of conversion of ME to net energy for maintenance was greater for steers than for bulls (68.8 and 65.6%, respectively), indicating that bulls had a 5.4% greater ME requirement for maintenance than steers. Most pastures can meet the energy requirement for maintenance, but not productive processes like growth, gestation or lactation which are much more energy-demanding.

Growth:

Growth in animals is defined as accretion of protein, fat, and bone (Owens et al. 1995). Although growth is typically measured as the change in live weight, nutrient retention is estimated more precisely by measuring empty body weight and composition, whereas production economics are measured ideally through carcass weights and quality (Coleman 1995). For fast-growing animals, high growth rate produces faster muscle protein accretion and greater efficiency of gain perhaps due to a lower maintenance cost or a greater efficiency of gain and because the rate of protein accretion depends on the relative rates of protein synthesis and degradation, rapidly growing animals must have a greater ratio of protein synthesis to protein degradation than slower growing animals (Castro Bulle *et al.* 2007).

Figure 8 illustrates the respective intakes of energy or protein needed for dairy heifers at various stages of development to gain 0.6, 0.7 or 0.8 kg/day, and the intakes achievable from irrigated grass pasture. Capacity of grain or concentrate supplementation to satisfy animal requirements is demonstrated. Good quality, fertilized grass alone will not support liveweight gains >0.6 kg/day until heifers reach about 250 kg live weight. Leafy pastures theoretically contain adequate protein for weaner calves, but it is insufficient to supply the protein required to balance high energy – low protein supplements (grain) until animals reach about 200 kg (Figure 8).

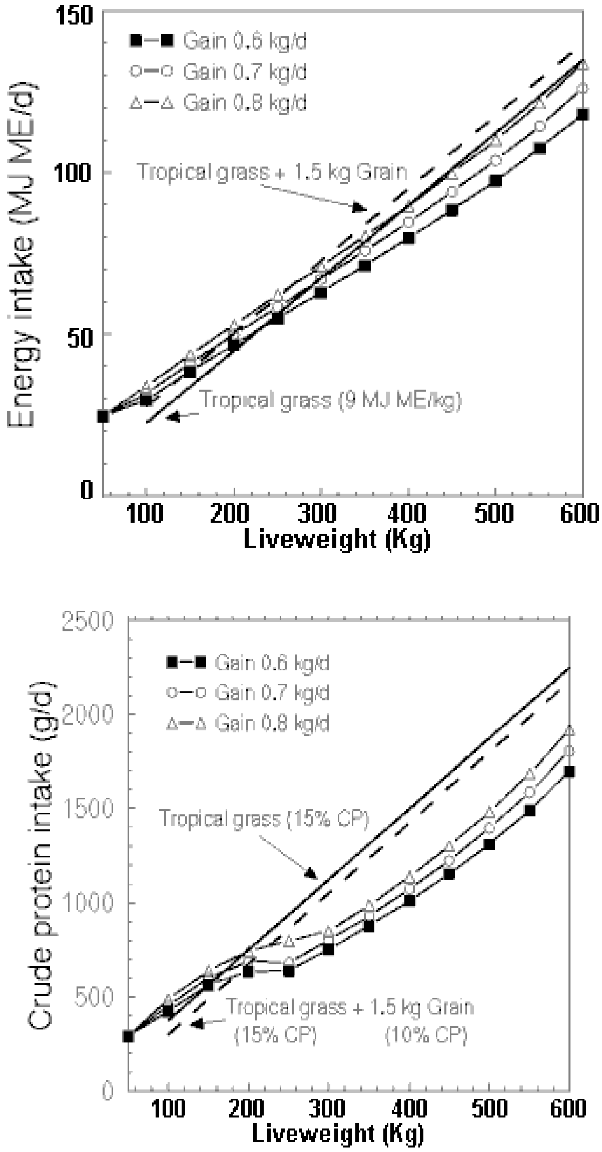


Figure 8 (a) Dietary energy (MJ ME/day) and (b) crude protein (g/day) requirements of dairy heifers at various rates of gain (NRC 1989) and the ability of grass pastures to satisfy these requirements. Assumed voluntary intake of pasture ~ 2.5% live weight (Moss & Goodchild 1992).

As a percentage of live weight gain in beef cattle, carcass weight gain is usually a much higher percentage during the feedlot phase than during the growing phase of production because dressing percentage (ratio of carcass:live weight) increases with maturation and is greater with concentrate than with roughage diets (Figure 9).

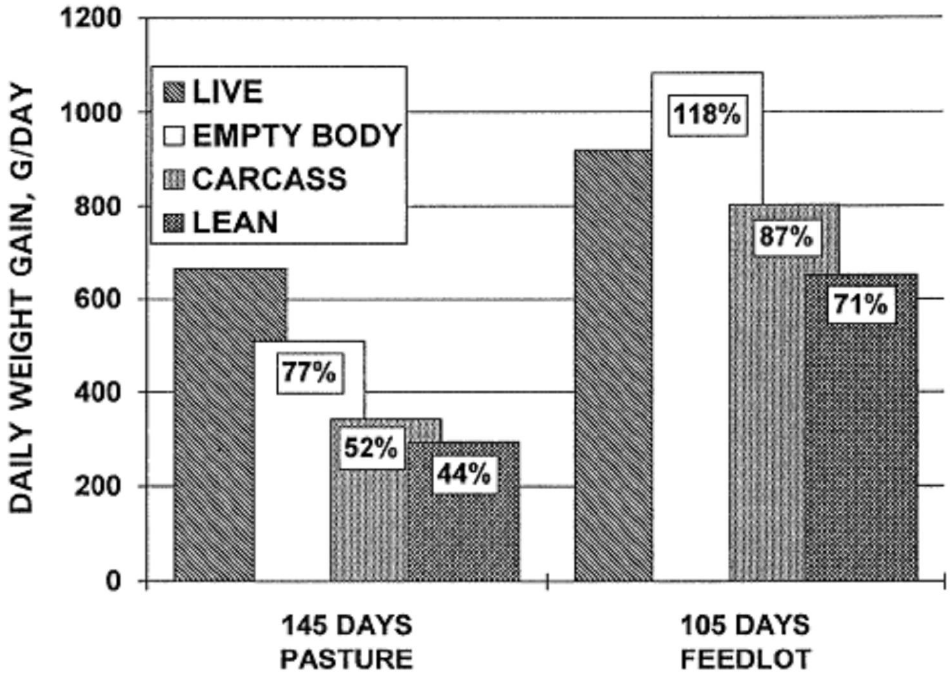


Figure 9. Relative rates of live, empty body, carcass, and lean gain by cattle during growing (backgrounding on either sorghum silage or limit-fed grain) and finishing (ad libitum access to grain) stages of production. Source: Coleman *et al.* (1995).

Pregnancy and lactation:

Evidence suggests that maternal nutrient intake at specific periods during pregnancy can influence subsequent development of the offspring (Wu *et al.* 2006) carcass characteristics and muscle fibre composition (Daniel *et al.* 2007). Martin *et al.* (2007) conducted a study with heifers to determine the effects of late gestation (LG) or early lactation (EL) dam nutrition on subsequent heifer growth and reproduction. In LG, cows received 0.45 kg/d of a 42% CP supplement (PS) or no supplement (NS) while grazing. During EL, cows from each late gestational treatment were fed cool-season grass hay or grazed sub-irrigated meadow. Heifers from PS dams had greater DMI and residual feed intake than heifers from NS cows if their dams were fed hay during EL but not if their dams grazed meadows. Heifers born to PS cows were heavier at weaning, prebreeding, first pregnancy diagnosis, and before their second breeding season. Heifers from cows that grazed meadows during EL were heavier at weaning but not postweaning. Despite similar ages at puberty and similar proportions of heifers cycling before the breeding season, a greater proportion of heifers from PS dams calved in the first 21 d of the heifers' first calving season, and pregnancy rates were greater compared with heifers from NS dams. Details of the nutrient requirements for pregnant and lactating cows are available from NRC (1989) and extracted by DeLaval (2007).

Concluding recommendations and suggestions

- Energy, crude protein and dry matter digestibility of pastures are essential components of quality that influence the voluntary intake of grazing livestock. To be able to meet the nutrient requirements of animals for maintenance, growth, gestation and lactation, pasture quality, quantity and efficient utilisation need to be well managed.

- Seasonal changes in pasture quality imply that a strategic and tactical approach to grazing management needs to be adopted in terms of herd structure, stocking rate and the use of persistent pasture species that can fill the seasonal feed gap.

- Pastures grazed in green, leafy vegetative condition have the highest nutritional quality. Growing and lactating animals should have priority access before dry stock due to their high nutrient requirements.

- Maintaining pasture mass above 1000kg green DM/ha promotes rapid growth and checks against overgrazing. Animal intake and pasture quality decline when the mass exceeds 3000kg green DM/ha, therefore, managing pastures to maintain between 1500-2500kg green DM/ha would enhance maximum cattle performance.

- Completely depending on pastures alone may not meet the nutritional requirements of lactating animals, particularly energy. Strategic supplementation with high-energy grains will fix this.

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